Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jobcr

Original Article

Reliability of India-specific regression formula for age estimation of population in and around Bahadurgarh, Haryana (India)

Ankita Tandon^{a,*}, Vartika Agarwal^b, Varun Arora^c^a Department of Oral Pathology & Microbiology, PDM Dental College and Research Institute, Bahadurgarh, Haryana, India^b Department of Public Health Dentistry, ITS Dental College Hospital & Research Institute, Greater Noida, Uttar Pradesh, India^c Research Consultant at APS and Visiting Faculty (Epidemiology and Biostatistics), Lucknow University, Lucknow, Uttar Pradesh, India

ARTICLE INFO

Article history:

Received 25 March 2015

Accepted 20 June 2015

Available online 29 July 2015

Keywords:

Age estimation

Demirjian's method

Forensic dentistry

India-specific

ABSTRACT

Objectives: The study was conducted to check the reliability of India-specific regression formula for age estimation of population in and around Bahadurgarh, Haryana (India).

Materials and methods: The study was conducted using digital orthopantomograms (OPGs) of 464 subjects (253 males and 211 females). Chronologic age (CA) was derived from that mentioned on the OPG. Each tooth in the left mandibular segment was scored using Demirjian's scoring and age was calculated using the regression formulas derived by Acharya. The difference of the chronologic and estimated age was used to check the reliability of India-specific regression formula.

Results: The mean estimated age was found to be significantly higher as compared to CA for overall as well as both the genders independently ($p < 0.001$). Difference (in $\pm$) between estimated and CA ranged from 0 to 4.2 years. Mean difference in age was 0.85 ± 0.73 years for males and 0.87 ± 0.76 years for females.

Conclusion: The published India-specific regression formula does not have reliability in the population of Bahadurgarh, Haryana and hence cannot be universally applied.

© 2015 Craniofacial Research Foundation. Published by Elsevier B.V. All rights reserved.

1. Introduction

Estimation of age is very significant in aspect of accordance with laws.¹ The age estimation process has to be highly accurate in predicting the individual's age and should be easy to use. In the current scenario, most of the age estimation

modalities are invasive, require lengthy processing times, use expensive instruments and services of an experienced pathologist to deduce the age of the person.^{2,3} Various methods of age estimation have been suggested in the literature which includes Gustafson's method, measurement of dentin translucency, counting annular cemental rings, calculating pulp-to-tooth ratio, using amino acid racemization, measuring ¹⁴C levels, etc.⁴

* Corresponding author.

E-mail addresses: tandon_ankita7@rediffmail.com, drankitatandon7@gmail.com (A. Tandon).
<http://dx.doi.org/10.1016/j.jobcr.2015.06.013>

2212-4268/© 2015 Craniofacial Research Foundation. Published by Elsevier B.V. All rights reserved.

But the biggest pitfall had been the lack of usability of these methods in-vivo.^{2,3} Radiographic approach, therefore, renders an insight into the developmental stages of the teeth, which provides a baseline data for age estimation.³

Hence, Demirjian et al.⁵ classified the development of teeth into 8 stages and derived an age estimation formula. The original method used only seven left mandibular teeth and assigned a gender-specific maturity score to each tooth. The scores were then summed up and compared with the charts to arrive at the age.⁵ This method has undergone a number of modifications, since then due to its lack of reliability in several subsequent studies.⁶

In order to overrule the differences in age detection, Acharya⁶ carried out a regression analysis and derived a formula incorporating third molars as well into the age estimation process in an Indian population. The aim of this study is to evaluate the reliability of the India-specific regression formula for age estimation of population in and around Bahadurgarh, Haryana (India).

2. Materials and methods

The study was carried on orthopantomograms (OPGs) retrieved from the Department of Oral Medicine and Radiology with the permission of the institutional ethical committee. The OPGs belonged to the age group of 7–21 years (males = 253 and females = 211, total = 464). OPGs with the full complement of teeth in the left mandibular segment were included in the study. Subjects with prior history of malnutrition and growth disorders as mentioned in the history proforma of the software were excluded. Also, OPGs with distortion of image, lack of contrast, dental crowding, and pathologies were not included in the study.

The sample size projection was based on the study of Kumar and Gopal³ who had reported the estimated age error within ± 1 year range in 44% of their samples. Considering this to be the targeted precision of ± 1 year in our study, we calculated the sample size using the following formula:

$$n = z^2 \frac{p(1-p)}{d^2},$$

where 'p' is the proposed prevalence (44% or 0.44), z is a constant having a value of 1.96 at 95% confidence and 80% power, and d is the proposed absolute error (5% or 0.05).

Putting these values in above equation, we get

$$n = 1.96^2 \frac{0.44(1-0.44)}{0.05^2} = 378.68 = 379$$

Thus the calculated sample size for the proposed precision level was 379. After adding for a contingency at 25% the projected sample size was 474. A total of 474 OPGs were collected, however, for 10 OPGs, the data were inappropriate and hence they were excluded from assessment. Finally, the sample size was 464, which is sufficient enough to explain the targeted precision.

The radiographs were divided into the following groups:

Group A: 7–10 years

Group B: 11–15 years

Group C: 16–18 years

Group D: 19–21 years

The images obtained from digital OPG machine (Panoramic X-Ray Imaging System, Pax 400 C, Vatech Co. Ltd, Korea) were converted to JPEG format. The digital images were then analyzed with Adobe Photoshop 7.0. During the analysis, 'Magnify' and 'Ruler' tools were used.

The teeth in the left mandibular segment were scored based on the Demirjian's modified criteria, which included ten stages of tooth development⁷ since at present no India-specific maturity scores have been proposed.³ The scores were summed up and age was estimated using the gender-specific regression formula proposed by Acharya.⁶

$$\text{Males: Age} = 27.4351 - (0.0097 \times S^2) + (0.000089 \times S^3)$$

$$\text{Females: Age} = 23.7288 - (0.0088 \times S^2) + (0.000085 \times S^3)$$

The calculated values were designated as the dental age (DA) and these were compared with the chronological ages (CA), which were obtained from the date of birth as recorded on the digital OPG. To rule out the intra-observer difference, 100 randomly selected radiographs were re-evaluated. The inter-observer agreeability was arrived by scoring 100 randomly selected radiographs between two observers, and the results obtained were compared. The statistical analysis was carried out using Statistical Package for Social Sciences, version 15.0. Data were represented as mean $\pm$ SD as number and percentages. Chi-square test, Student 't'-test, and paired 't'-test were used for comparison purposes. The confidence level of the study was kept at 95%, hence a "p" value less than 0.05 indicated a significant association.

3. Results

A total of 464 subjects were enrolled in the study. Majority of them were males ($n = 253$; 54.5%). Age of subjects ranged from 7 to 21 years with a mean age of 15.34 ± 3.92 years. Maximum number of subjects in both the genders was aged 11–15 years. Mean age of boys was 15.28 ± 3.98 and that of girls was 15.41 ± 3.86 years. Statistically, there was no significant difference in mean age of subjects between two genders ($p = 0.737$) (Table 1).

On comparing the CA with estimated age using India-specific regression formula, mean estimated age was found to be significantly higher as compared to CA for overall as well as both the genders independently ($p < 0.001$) (Table 2).

On comparing the difference between CA and estimated age in different chronologic age groups, the pattern of difference remained same with estimated age being higher as compared to CA and difference between estimated age and CA was significant statistically too ($p < 0.05$) for all the chronologic age groups except age group 16–18 years ($p = 0.061$).

On evaluating this relationship for the two genders separately, males showed a similar trend with mean estimated age being higher as compared to CA for all the chronologic age groups and the difference being significant statistically too for all chronologic age groups ($p < 0.05$) except age group 7–10 years ($p = 0.121$) and 16–18 years ($p = 0.236$). Among females too, the

Table 1 – Sample profile and characteristics.

S. no	Characteristic	Statistic		
1.	Gender			
	Male	253 (54.5%)		
	Female	211 (45.5%)		
2.	Age	Male (n = 253)	Female (n = 211)	Total (n = 411)
	7–10 years	22 (8.7%)	16 (7.6%)	38 (8.2%)
	11–15 years	103 (40.7%)	96 (45.5%)	199 (42.9%)
	16–18 years	55 (21.7%)	40 (19.0%)	95 (20.5%)
	19–21 years	73 (28.9%)	59 (28.0%)	132 (28.4%)
	Mean age $\pm$ SD (range)	15.28 $\pm$ 3.98 (7–21)	15.41 $\pm$ 3.86 (7–21)	t = 0.336; p = 0.737 (NS)

Independent samples 't'-test.

Table 2 – Comparison between chronologic and estimated age mean $\pm$ SD (years).

S. no	Characteristic	n	Chronologic age	Estimated age	Significance of difference (paired 't'-test)
1.	Overall	464	15.34 $\pm$ 3.92	15.73 $\pm$ 4.05	t = 7.770; p < 0.001
2.	Males	253	15.28 $\pm$ 3.98	15.63 $\pm$ 4.18	t = 5.127; p < 0.001
3.	Females	211	15.41 $\pm$ 3.86	15.84 $\pm$ 3.89	t = 5.904; p < 0.001

Table 3 – Comparison between chronologic and estimated age for different chronologic age groups (mean $\pm$ SD (years)).

S. no	Characteristic	n	Chronologic age	Estimated age	Difference	Significance of difference (paired 't'-test)
(a) Overall (both genders)						
1.	7–10 years	38	7.97 $\pm$ 1.05	8.43 $\pm$ 1.53	0.46 $\pm$ 0.88	t = 3.203; p < 0.001
2.	11–15 years	199	12.78 $\pm$ 1.41	13.19 $\pm$ 1.73	0.41 $\pm$ 1.02	t = 5.683; p < 0.001
3.	16–18 years	95	17.24 $\pm$ 0.75	17.45 $\pm$ 1.29	0.21 $\pm$ 1.06	t = 1.900; p = 0.061
4.	19–21 years	132	19.95 $\pm$ 0.87	20.41 $\pm$ 1.45	0.46 $\pm$ 1.19	t = 4.419; p < 0.001
(b) Males						
1.	7–10 years	22	8.09 $\pm$ 1.15	8.42 $\pm$ 1.65	0.33 $\pm$ 0.96	t = 1.616; p = 0.121
2.	11–15 years	103	12.51 $\pm$ 1.20	12.82 $\pm$ 1.59	0.31 $\pm$ 1.00	t = 3.135; p = 0.002
3.	16–18 years	55	17.09 $\pm$ 0.78	17.28 $\pm$ 1.27	0.19 $\pm$ 0.94	t = 1.485; p = 0.143
4.	19–21 years	73	20.00 $\pm$ 0.82	20.51 $\pm$ 1.50	0.51 $\pm$ 1.25	t = 3.492; p = 0.001
(c) Females						
1.	7–10 years	16	7.81 $\pm$ 0.91	8.44 $\pm$ 1.41	0.63 $\pm$ 0.74	t = 3.392; p = 0.004
2.	11–15 years	96	13.06 $\pm$ 1.57	13.58 $\pm$ 1.80	0.52 $\pm$ 1.02	t = 4.936; p < 0.001
3.	16–18 years	40	17.45 $\pm$ 0.68	17.68 $\pm$ 1.30	0.23 $\pm$ 1.22	t = 1.203; p = 0.236
4.	19–21 years	59	19.90 $\pm$ 0.94	20.29 $\pm$ 1.39	0.39 $\pm$ 1.11	t = 2.692; p = 0.009

trend was similar as for combined assessment and males, however, among females the difference was significant statistically for all the age groups except age group 16–18 years (p = 0.236) (Table 3a–c).

Difference (in $\pm$) between estimated and CA ranged from 0 to 4.2 years. Majority of subjects had more than 6 months difference between estimated and CA (n = 290; 62.5%). There

were 63 (13.6%) subjects having a difference of 0–3 months between estimated and CA and 111 (23.9%) with a difference of 3–6 months. Maximum had a difference of 6–12 months (n = 177; 38.1%). A total of 35 (7.5%) had a difference of 2–3 years and 10 (2.2%) had a difference of >3 years. Mean difference was 0.86 $\pm$ 0.74 years. Mean difference in age was 0.85 $\pm$ 0.73 years for males and 0.87 $\pm$ 0.76 years for females. On

Table 4 – Comparison of extent of deviation from chronologic age in different age groups and between two genders.

S. no	Range of difference	Total (n = 464)		Males (n = 253)		Females (n = 211)	
		n	%	n	%	n	%
1.	0–3 months	63	13.6	35	13.8	28	13.3
2.	3–6 months	111	23.9	59	23.3	52	24.6
3.	6–12 months	177	38.1	97	38.3	80	37.9
4.	1–2 years	68	14.7	39	15.4	29	13.7
5.	2–3 years	35	7.5	18	7.1	17	8.1
6.	>3 years	10	2.2	5	2.0	5	2.4
Mean difference $\pm$ SD (range)		0.86 $\pm$ 0.74 (0–4.2)		0.85 $\pm$ 0.73 (0–4.0)		0.87 $\pm$ 0.76 (0–4.2)	

 $\chi^2 = 0.554$; p = 0.990.

comparing the magnitude of differences between two genders, the difference was not found to be significant statistically ($p = 0.990$) (Table 4).

4. Discussion

Dental maturation is a complex sequence of events from initial mineralization of a tooth, crown formation, root growth, eruption of tooth into the mouth, and root apex maturation.⁸ Developing teeth are generally considered to be the most useful and reliable indicators of maturation, because they are less affected than other body tissues by endocrinopathies and environmental insults, exogenic factors such as malnutrition or disease.^{8,9} The dental system is an integral part of the human body; its growth and development can be studied in parallel with other physiological maturity indicators such as bone age, menarche, and height.¹⁰

DA determination is required in various clinical and scientific disciplines such as pediatric dentistry, orthodontics, archeology, paleontology, and forensic dentistry. In certain communities, the CA of living people bears significant importance regarding social benefits, employment, retirement, and marriage.¹¹ The need for age estimation has certain important reasons at certain specific age groups in the Indian context: (1) 12 years: children below this age are not liable for certain offenses; (2) 14 years: a child cannot be employed below 14 years; (3) 18 years: determines the status of maturity and the legally permissible age for marriage in females; (4) 21 years: the legally permissible age of marriage in males.³

The original method proposed by Demirjian⁵ relied on the mandibular left side teeth from the central incisor to the second molar and had assigned eight stages of development, which were categorized as A to H. A score was assigned as a function of age and the predictive interval was given for the maturity score and computed to obtain the age.⁵ The original Demirjian's method excluded the third molar due to the variability in its development, eruption, and anatomy¹²; however Demirjian's method had a high accuracy⁷ (75.6% of our study population had estimated age within ± 1 year range of CA). Furthermore, when the method was applied to the Indian population, it resulted in an average overestimation of about 3 years.¹³ When evaluating the dental developmental stages based on the method of Demirjian⁵ it has to be considered that these values refer to a specific population sample. As a consequence, the genetic heritage of the investigated patient collective has to be taken into account when utilizing this method. The different cultural backgrounds lead to marked differences in the dental developmental stages, a fact which has been underlined in numerous studies.⁵

Demirjian method principally estimates the DA, which is dependent on the growth pattern of a population. The growth pattern is in turn dependent on a host of factors including life stage, CA, hormonal/biochemical changes, and nutritional pattern of a population. Thus, the estimation of Demirjian method across all the age groups and for both the genders is not uniform. The findings in the present study highlighted this point and indicated that in our population the Demirjian estimates correlated best with CA in 7–10 years of males and 16–18 years of both males and females.

In previous studies, Demirjian's method has been tested in different populations. In all populations, the authors have obtained an overestimation of DA ranging from 0.02 to 3 years.⁸ Koshy and Tandon recorded an overestimation of 2.82 years for females and 3.04 years for males in an Indian population using Demirjian's method.⁸

Hence to overcome the shortcomings, multiple regression analysis was used to obtain an age with a confidence interval as a function of score and also to limit the problems of missing data for which the India-specific regression formula was derived.^{3,14} However, in a study of age estimation in South Indian population the India-specific regression formula overestimated the age by 1.72 years in males and 1.91 years in females.¹⁵ In accordance with these findings our study also recorded an overestimation of age using India-specific formula in a range of 0–4.2 years. Out of this, 38.1% (maximum) population had 6–12 months difference of estimated and CA.

5. Conclusion

The India-specific regression formula appears to be sound and has an upper hand over the original method of Demirjian. This formula however did not fit in the Haryana population as all the estimated ages were higher as compared to actual CA. Hence the correction suggested for India-specific (which is in terms of addition) lacks empiricity and cannot be generalized.

Conflicts of interest

The authors have none to declare.

REFERENCES

1. Celik S, Zeren C, Celikel A, Yengil E, Altan A. Applicability of the Demirjian method for dental assessment of southern Turkish children. *J Forensic Leg Med.* 2014;25:1–5.
2. Willems G, Moulin-Romsee C, Solheim T. Non-destructive dental-age calculation methods in adults: intra and inter observer effects. *Forensic Sci Int.* 2002;126(3):221–226.
3. Kumar VJ, Gopal KS. Reliability of age estimation using Demirjian's 8 teeth method and India-specific formula. *J Forensic Dent Sci.* 2011;3(1):19–22.
4. Rajendran R, Sivapathasundharam B. *Shafer's Textbook of Oral Pathology.* 7th ed. India: Elsevier; 2012:894–896.
5. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. *Hum Biol.* 1973;45(2):211–227.
6. Acharya AB. Age estimation in Indians using Demirjian's 8-teeth method. *J Forensic Sci.* 2011;56(1):124–127.
7. Chaillet N, Demirjian A. Dental maturity in South France: a comparison between Demirjian's method and polynomial functions. *J Forensic Sci.* 2004;49(5):1059–1066.
8. Mohammed RB, Koganti R, Kalyan SV, Tircouveluri S, Singh JR, Srinivasulu E. Digital radiographic evaluation of mandibular third molar for age estimation in young adults and adolescents of South Indian population using modified Demirjian's method. *J Forensic Dent Sci.* 2014;6(3):191–196.
9. Willershausen I, Försch M, Willershausen B. Possibilities of dental age assessment in permanent teeth: a review.

- Dentistry. 2012;S1:001. <http://dx.doi.org/10.4172/2161-1122.S1-001>.
10. Manjunatha BS, Soni NK. Estimation of age from development and eruption of teeth. *J Forensic Dent Sci.* 2014; 6(2):73–76.
 11. Mohammed RB, Krishnamraju PV, Prasanth PS, Sanghvi P, Lata Reddy MA, Jyotsna S. Dental age estimation using Willems method: a digital orthopantomographic study. *Contemp Clin Dent.* 2014;5(3):371–376.
 12. Solari AC, Abramovitch K. The accuracy and precision of third molar development as an indicator of chronologic age in Hispanics. *J Forensic Sci.* 2002;47(3):531–535.
 13. Koshy S, Tandon S. Dental age assessment: the applicability of the assessment in south Indian children. *Forensic Sci Int.* 1998;94(1–2):73–85.
 14. Teivens A, Mörnstad H. A modification of the Demirjian method for age estimation in children. *J Forensic Odontostomatol.* 2001;19(2):26–30.
 15. Kiran Ch., Reddy RS, Ramesh T, Madhavi NS, Ramya K. Radiographic evaluation of dental age using Demirjian's eight-teeth method and its comparison with Indian formulas in South Indian population. *J Forensic Dent Sci.* 2015;7(1):44–48.